Cycles of the Moon

Phases, Libration, etc.

the Visible Sky

I. Stars and Celestial Sphere
Constellations & Coordinates

II. Sun
Time, Seasons, Precession

III. Moon
Phase, Orbit, etc.

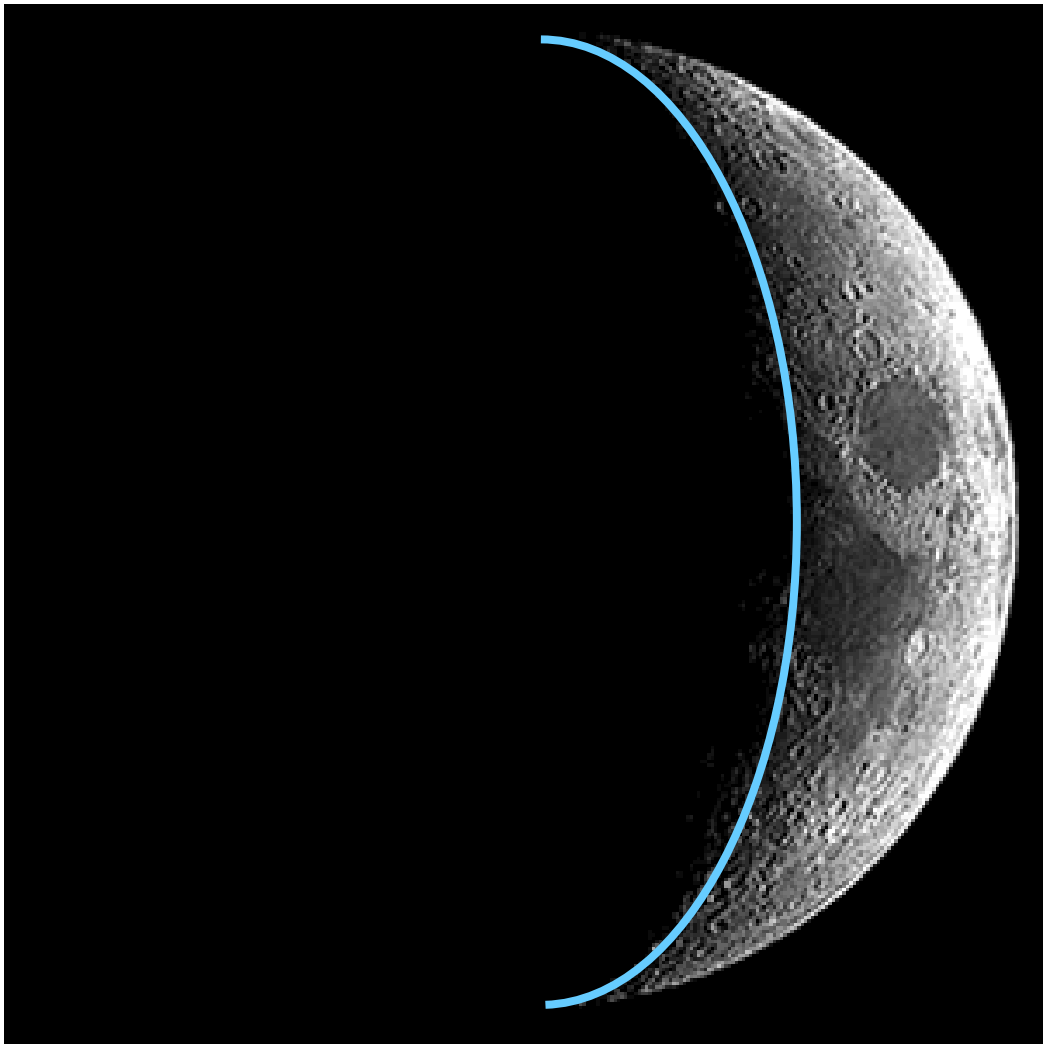
IV. Eclipses
Solar & Lunar

	The student will be able to:	HW:
1	Explain and utilize constellations and asterisms as means of mapping and organizing the stars.	1 – 4
2	Explain and utilize the concept of the celestial sphere as a means of understanding the appearance of the universe as seen from Earth.	
3	Explain the significance of the pole star, Polaris, and its connection with the apparent motion of the celestial sphere.	
4	Explain, define, and utilize the celestial equatorial coordinate system of right ascension and declination, celestial equator and celestial poles.	
5	Describe changes in position and appearance of the stars through time and explain in terms of the actual motion and position of the Earth.	5
6	Define, apply, and relate to astronomical events or cycles the following time concepts: sidereal and solar day, sidereal and tropical year, mean solar time, standard time, daylight savings time, and universal time.	6
7	Use a planisphere to locate celestial objects for a particular date and time and/or determine the date and time of certain celestial events.	7 – 8
8	Describe changes in position and appearance of the Sun through time and explain in terms of the actual motion and position of the Earth.	9
9	State the constellations of the zodiac in order and explain the relation between the zodiac and the Sun.	10 – 14
10	Explain, define, and utilize the concept of the ecliptic and the ecliptic plane.	
11	Illustrate and describe the connection between the seasons and the motion and orientation of the Earth in its orbit.	15
12	Explain the cause and effect of Earth's precession and state and apply the period of this cycle to solve problems.	16
13	Describe changes in the appearance of the Moon over the course of one day and night, from one night to the next, from one week to the next, from one month to the next, and from year to year.	17 – 20
14	Explain the apparent motion and changing appearance of the Moon in terms of the actual motions of the Earth and Moon relative to the Sun.	
15	Explain and illustrate how the motion and position of the Moon relative to the Earth and the Sun result in the phases: new Moon, waxing crescent, first quarter, waxing gibbous, full Moon, waning gibbous, third quarter, and waning crescent.	
16	Define, apply, and relate to astronomical events or cycles the following concepts: sidereal month, synodic month, lunar sidereal and solar days.	21 – 22
17	Explain and illustrate how the motions and positions of the Earth, the Sun, and the Moon result in lunar and solar eclipses – partial, total, and annular.	23
18	Explain and illustrate the concepts of umbra and penumbra in relation to eclipses.	24

Appearance of the Moon

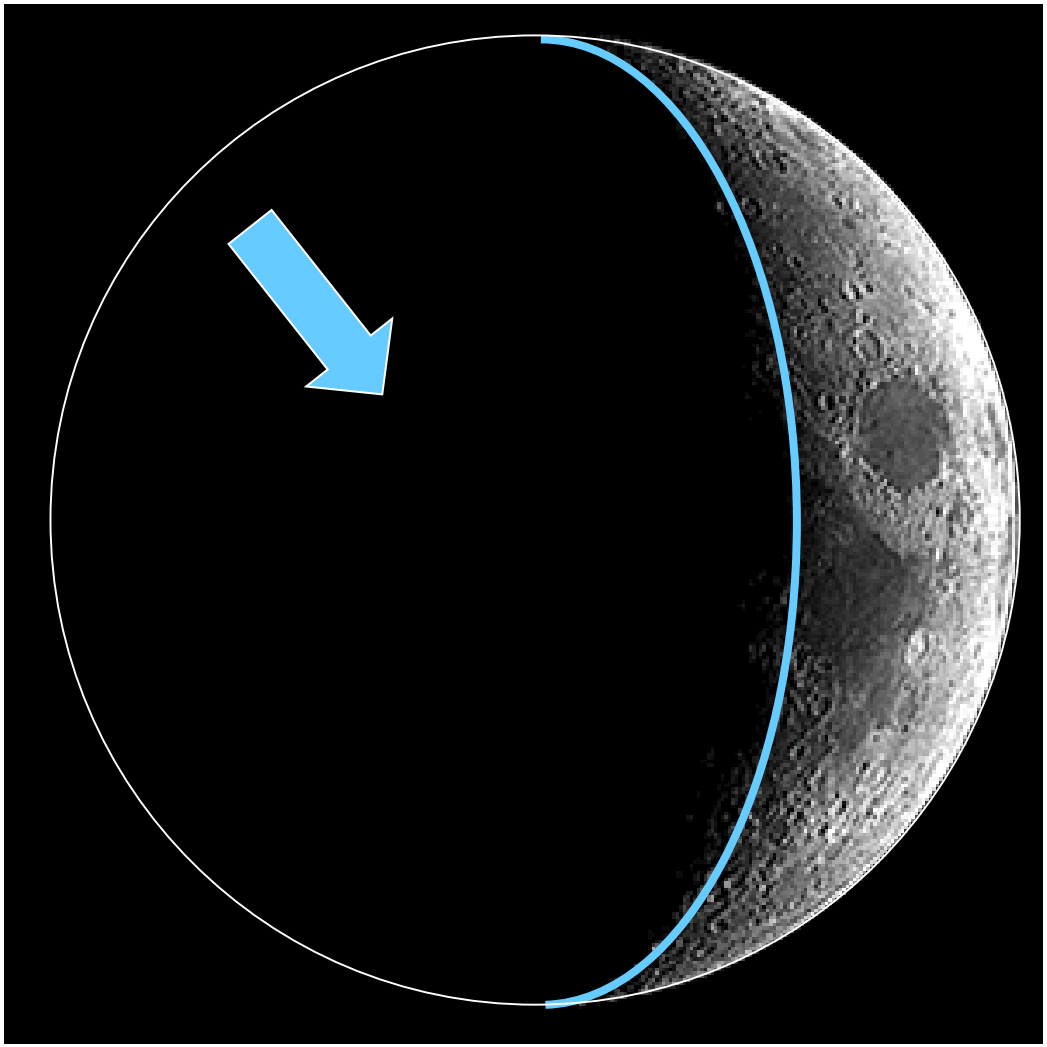
- Like the Sun, the Moon appears to rise in the East and set in the West over the course of several hours.
- Over the course of a month the “phase” of the Moon changes from crescent to full back to crescent.
- The Moon appears to move relative to the stars, somewhat like the Sun’s apparent motion along the ecliptic.

The Terminator



The “terminator” is the line dividing the illuminated and shadowed parts of the Moon.

The Terminator



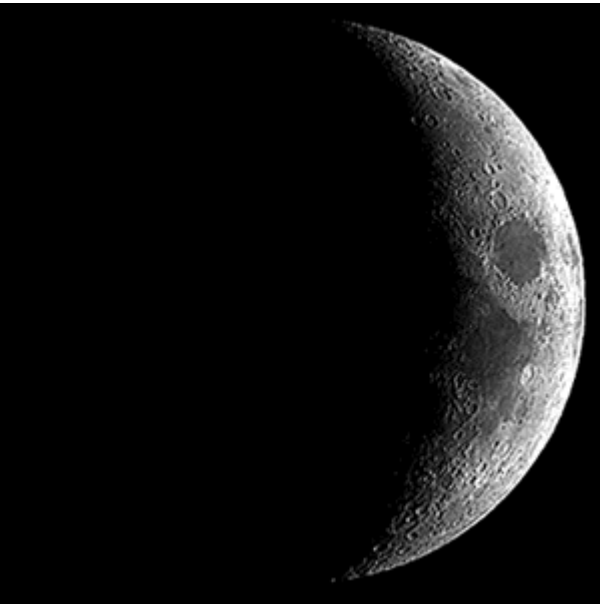
Q. What causes the dark (shadowed) part of the Moon?

A. It is the Moon's own shadow.
It is the "night side" of the Moon.

Phases

- A complete cycle of phases is called a *lunation* and defines a **synodic month**, which has a mean value of 29.53 days.
- The progression of the cycle is described in terms of the “age” of the Moon and the shape of the illuminated portion.

Describing the Moon's "Shapes"



Crescent

Gibbous

Quarter

Describing the *Changing* Phases

Waxing means *increasing* in size or intensity.

Waning means *decreasing* in size or intensity.

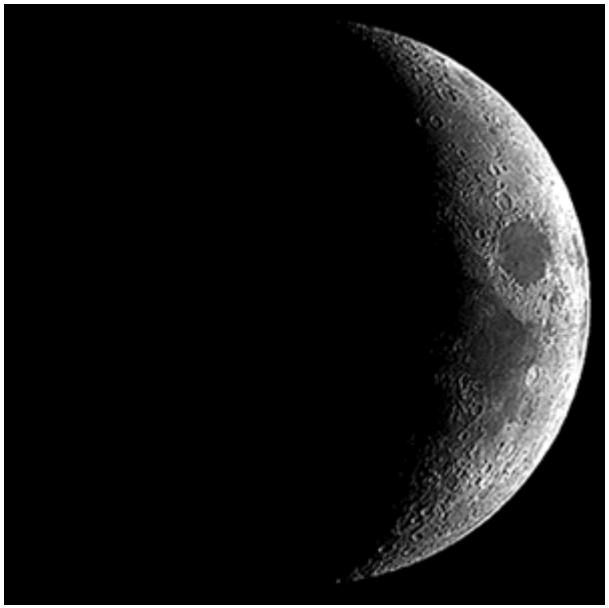
New Moon

Age = 0 days

Waxing Crescent

Age = 3 days

Waxing Crescent



Age = 5 days

1st Quarter

Age = 7 $^{3}/_{8}$ days

Waxing Gibbous

Age = 10 days

Waxing Gibbous

Age = 12 days

Full Moon

Age = 14 ¾ days

Waning Gibbous

Age = 16 days

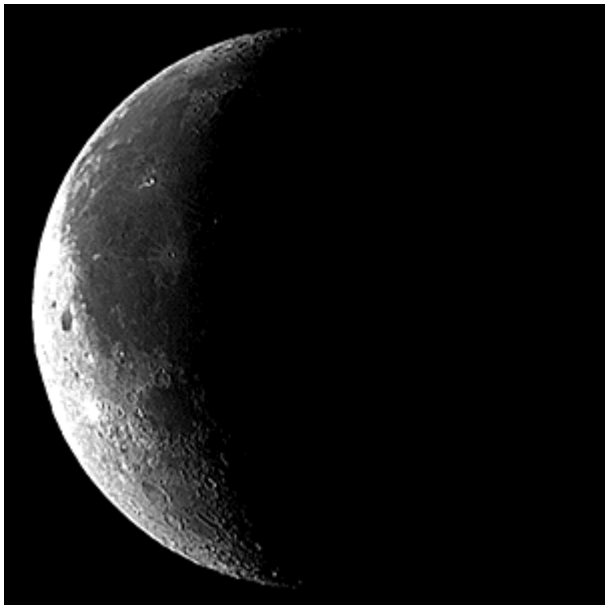
Waning Gibbous

Age = 18 days

3rd Quarter (almost)

Age = 22 days

Waning Crescent



Age = 25 days

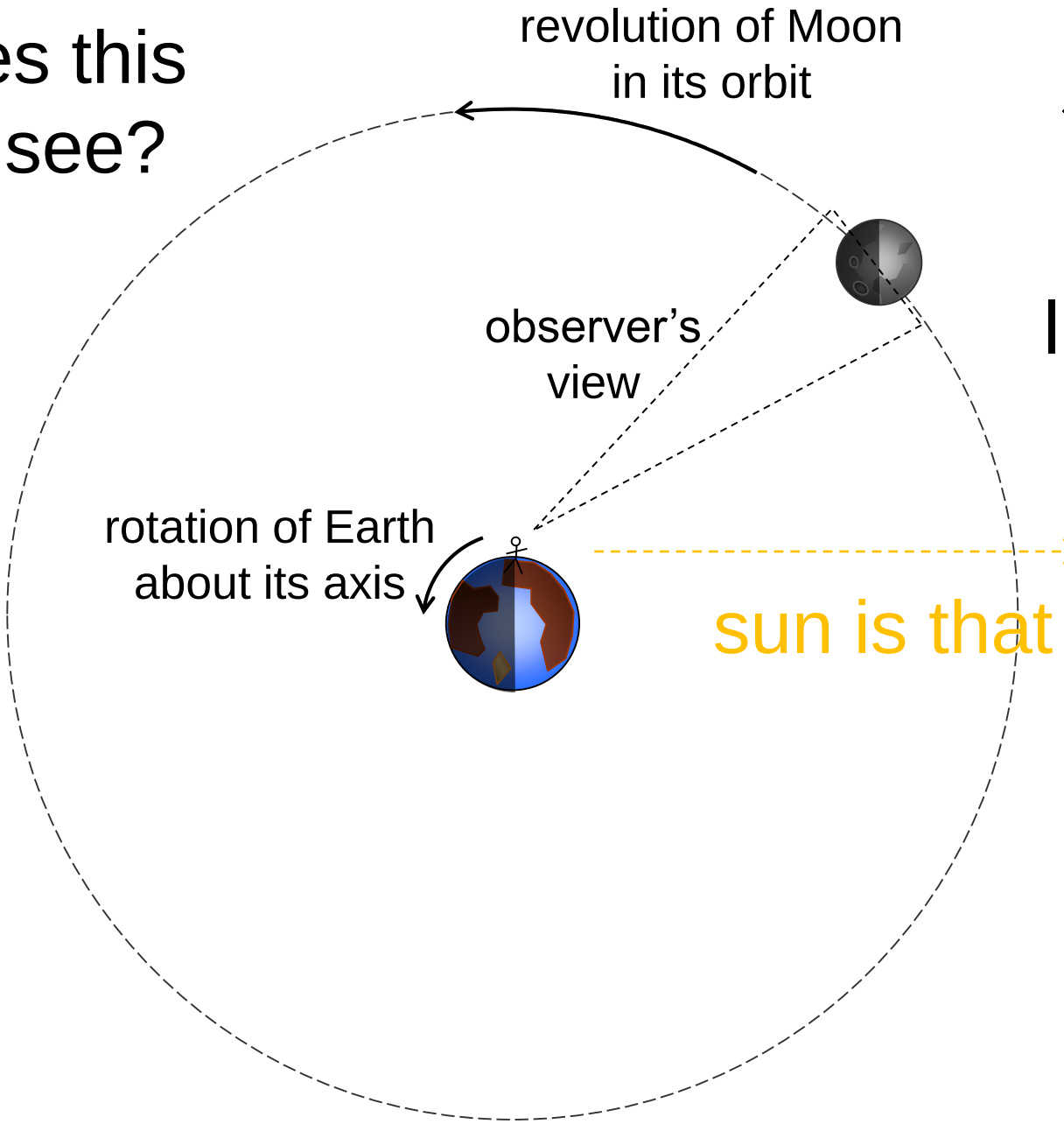
Waning Crescent

Age = 27 days

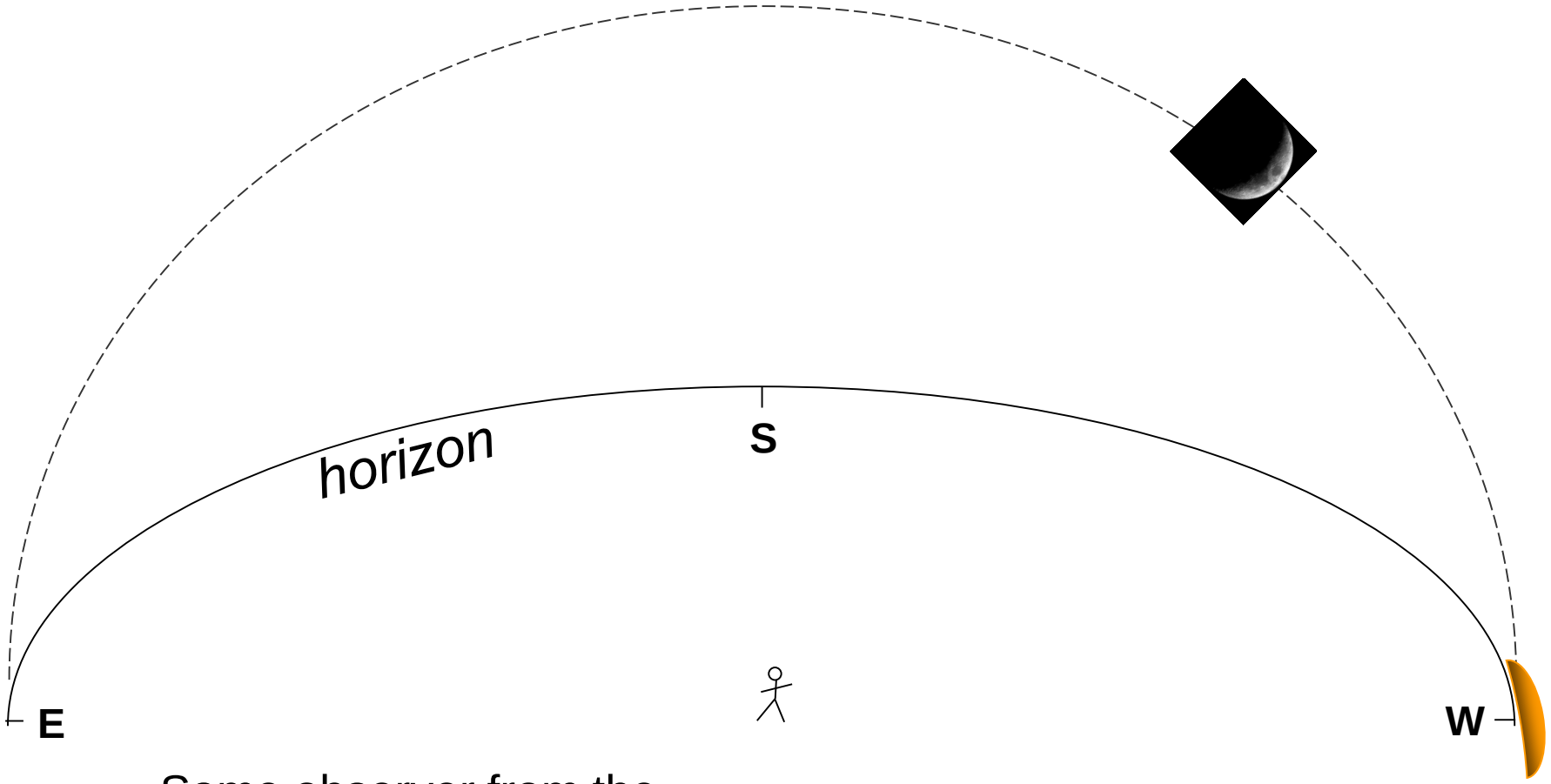
(almost) New Moon

Age = 29.4 days is an
“Old Moon”!

What does this observer see?



looks like this

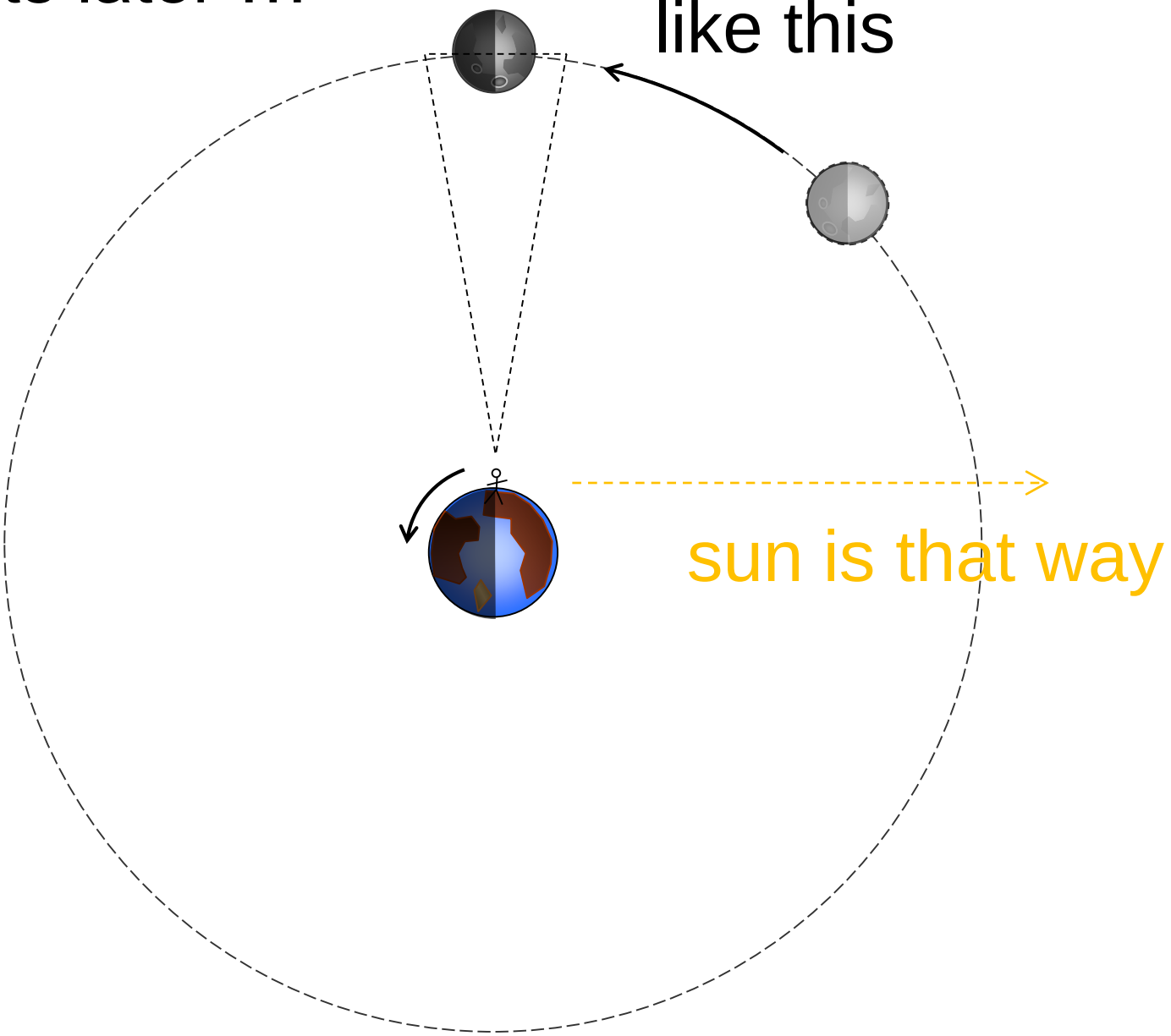


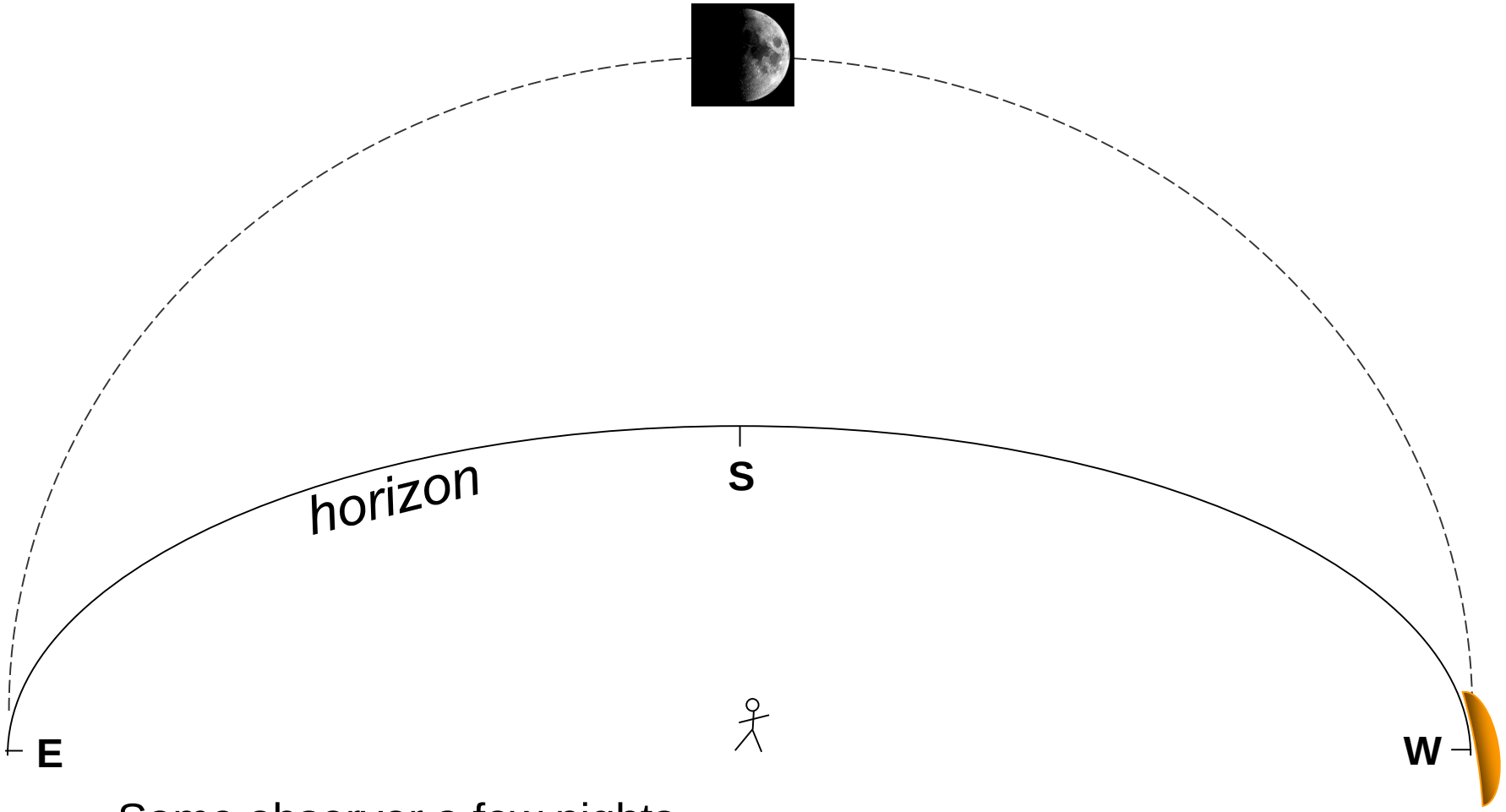
Same observer from the previous page would have this view of the waxing crescent – relatively low in the sky above the southwest horizon.

… at sunset

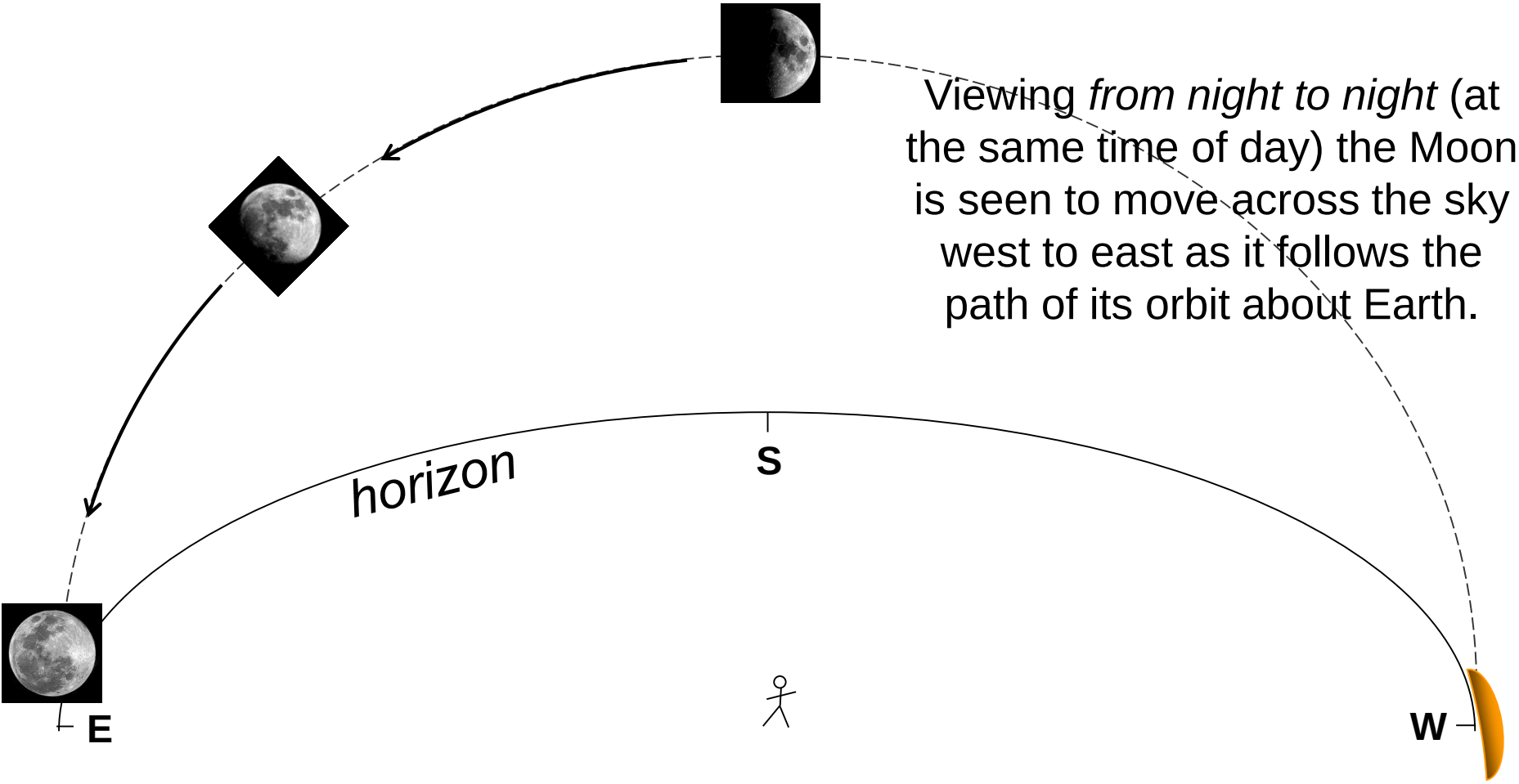
A few nights later …

looks like this





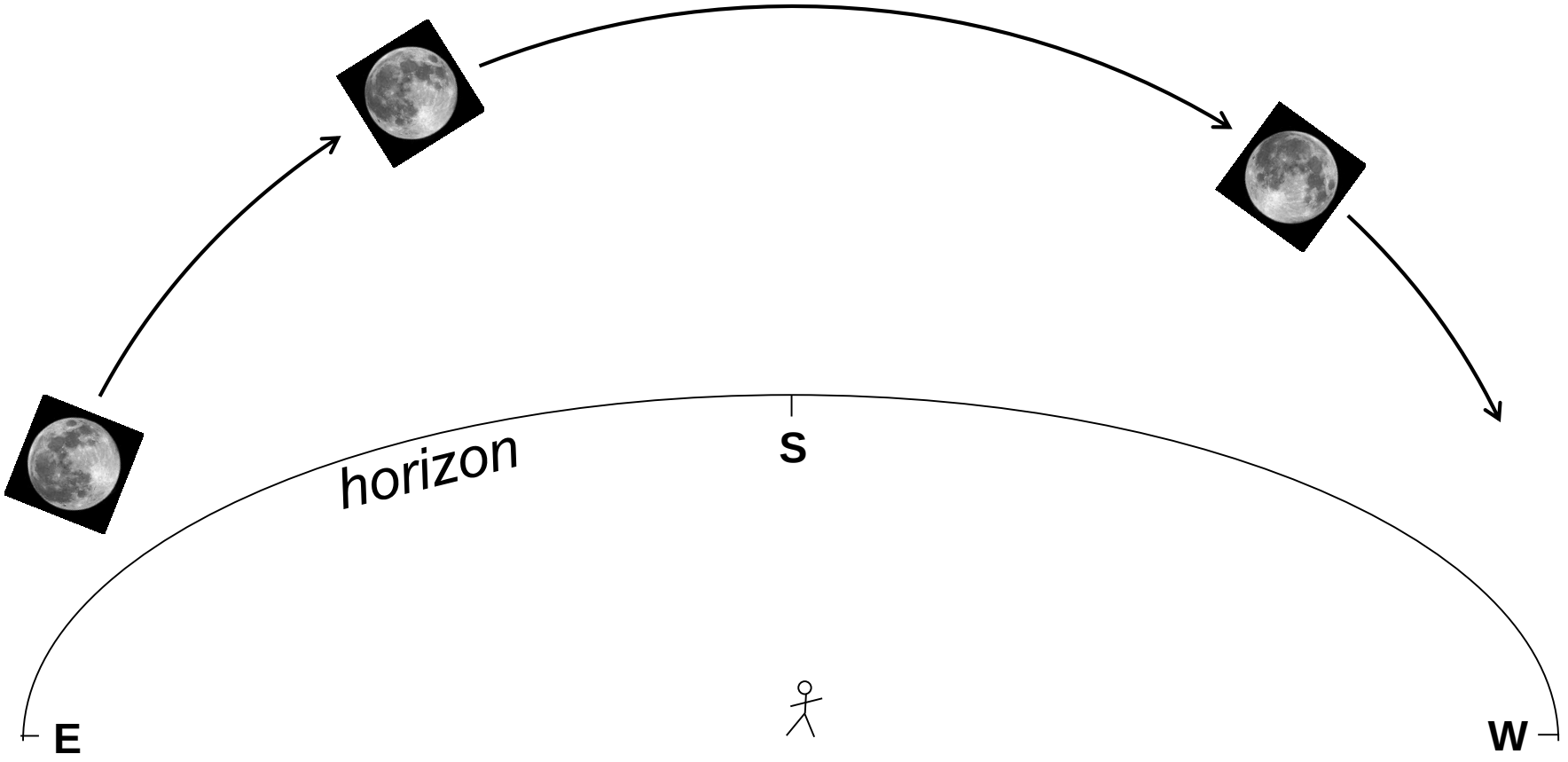
Same observer a few nights later sees the Moon at 1st quarter – relatively high in the sky above the south horizon at sunset.



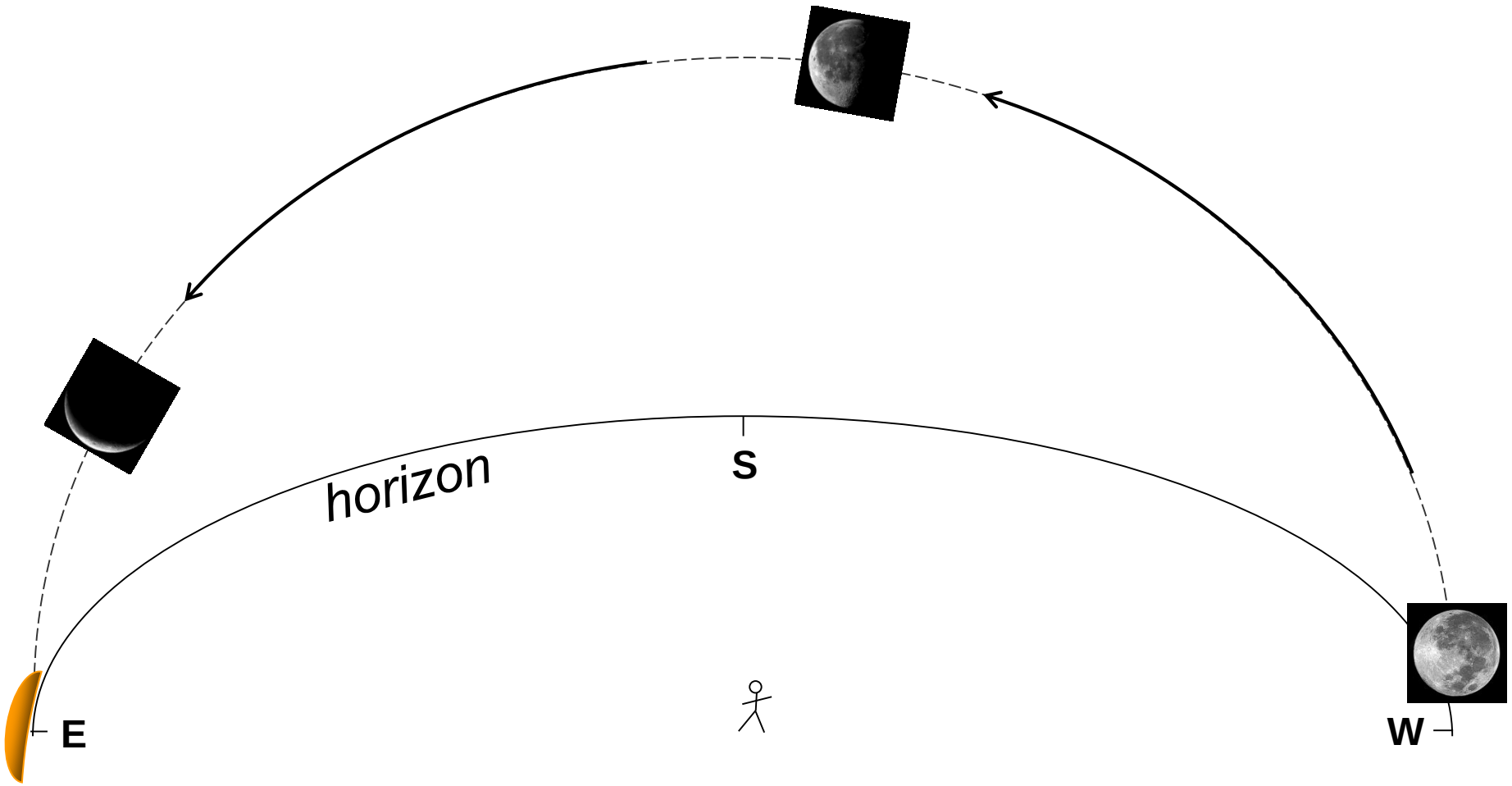
Viewing *from night to night* (at the same time of day) the Moon is seen to move across the sky west to east as it follows the path of its orbit about Earth.

… a few evenings later …

Viewing *from hour to hour* (during the same evening) the Moon is seen to move across the sky east to west as the Earth rotates.

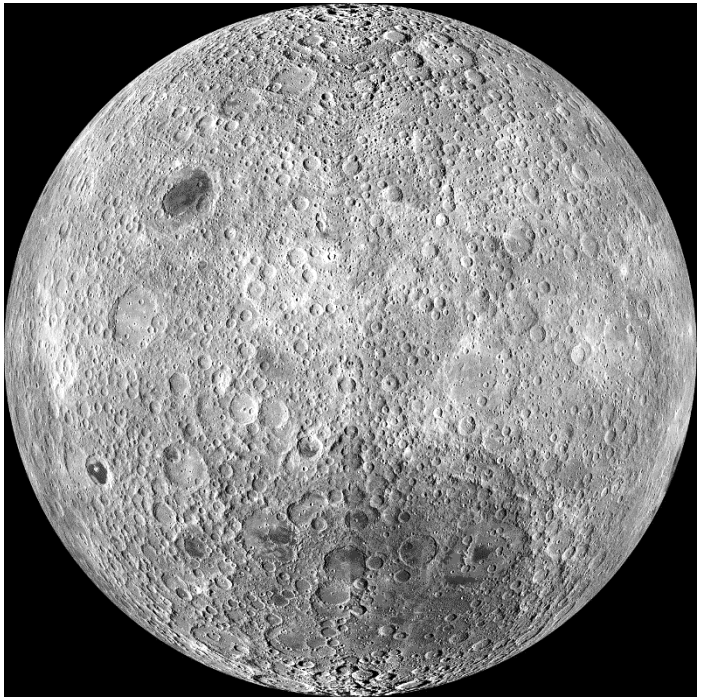


… during the night of the full Moon …



… at sunrise

Once the Moon is in the waning part of a lunation it becomes a “morning object” – highest in the sky and easiest to observe after midnight and before sunrise. This view imagines what is seen over 12 days going from Full to Waning Crescent…

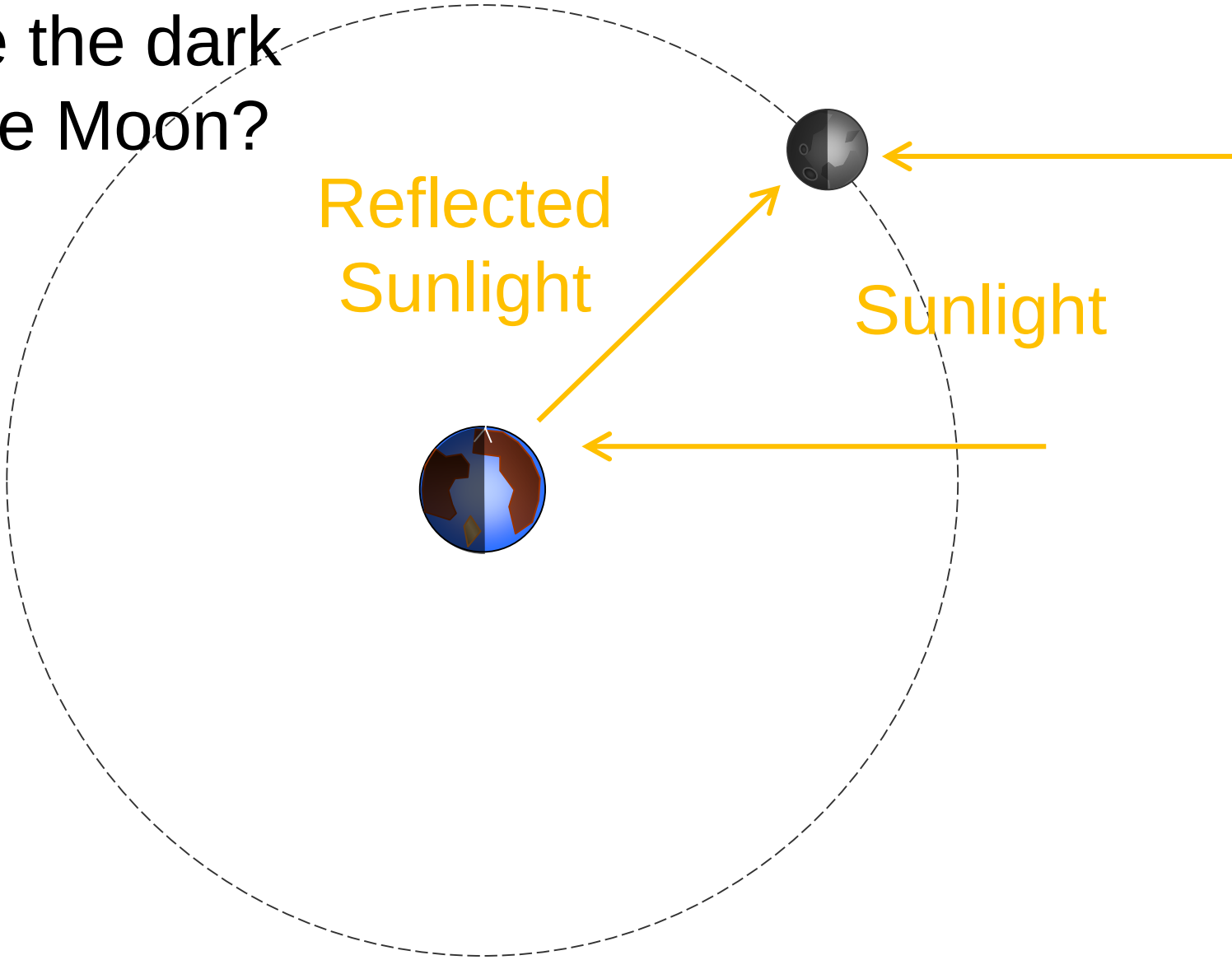


From Earth we can only see about half of the Moon at a time. And for the most part we see the ***same half*** at all times.

The *other* half of the Moon faces away from Earth at all times and was “unknown” until the advent of spacecraft. In this sense it is the “dark side” of the Moon.

When the Moon is a narrow crescent it is sometimes possible to see the darkened side of the Moon. Why?

What would illuminate the dark side of the Moon?

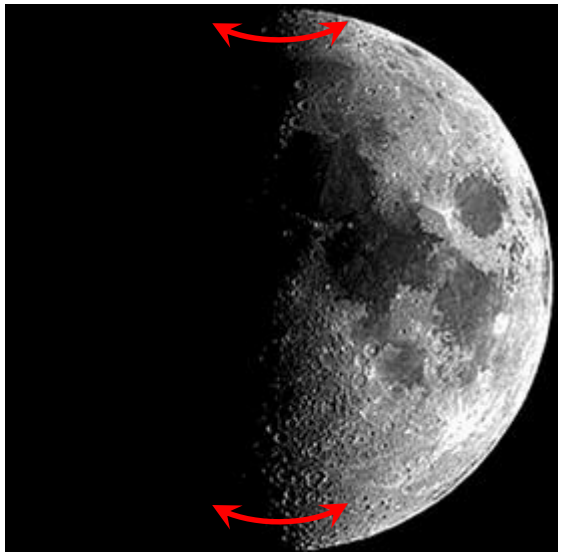


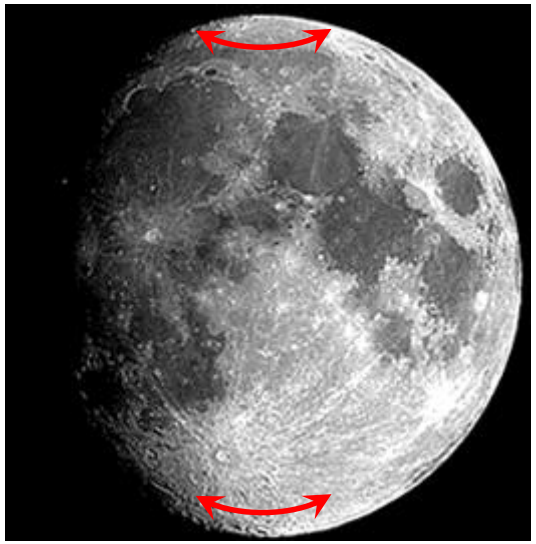
When the Moon is a narrow crescent it is sometimes possible to see the darkened side of the Moon. Why?

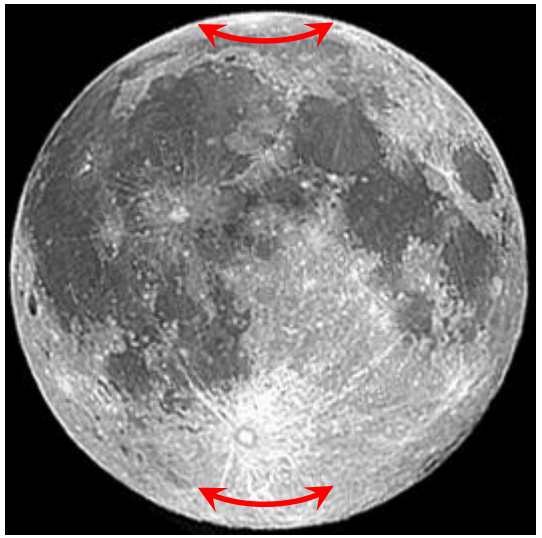
"The Old Moon in the New Moon's Arms."

The phenomenon is called "earthshine" because light reflects off of Earth and onto the shadowed part of the Moon.

Libration



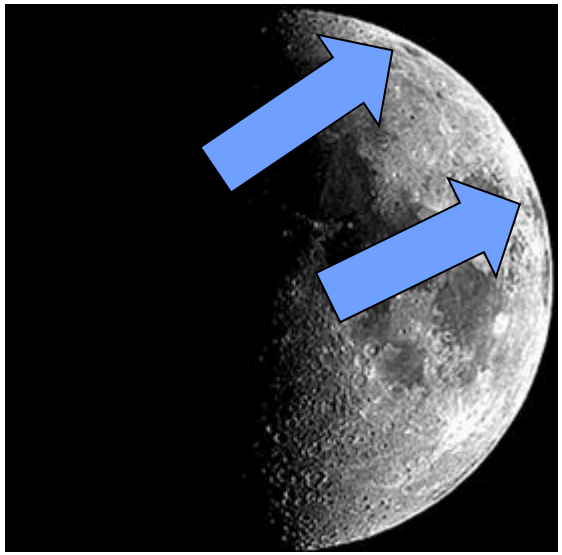


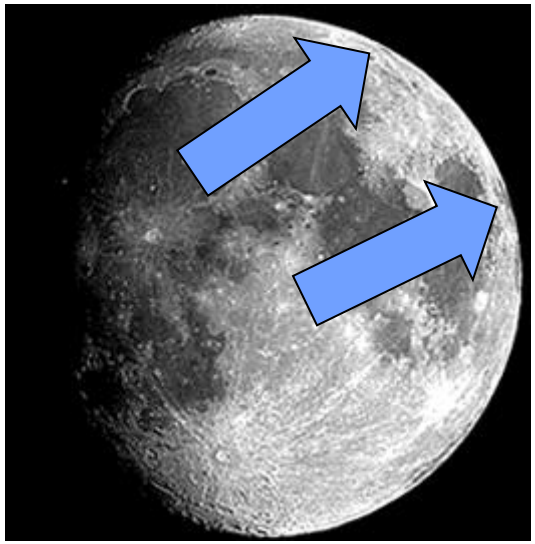


The Moon appears to rock slightly back and forth – it is said to librate.

Because of libration it is possible to see about 59% of the Moon's surface.

Arrows point to features that are visible in the first two images but not in the third. In this way we see the same “side” of the Moon but libration gives us “glimpses around the edge”.



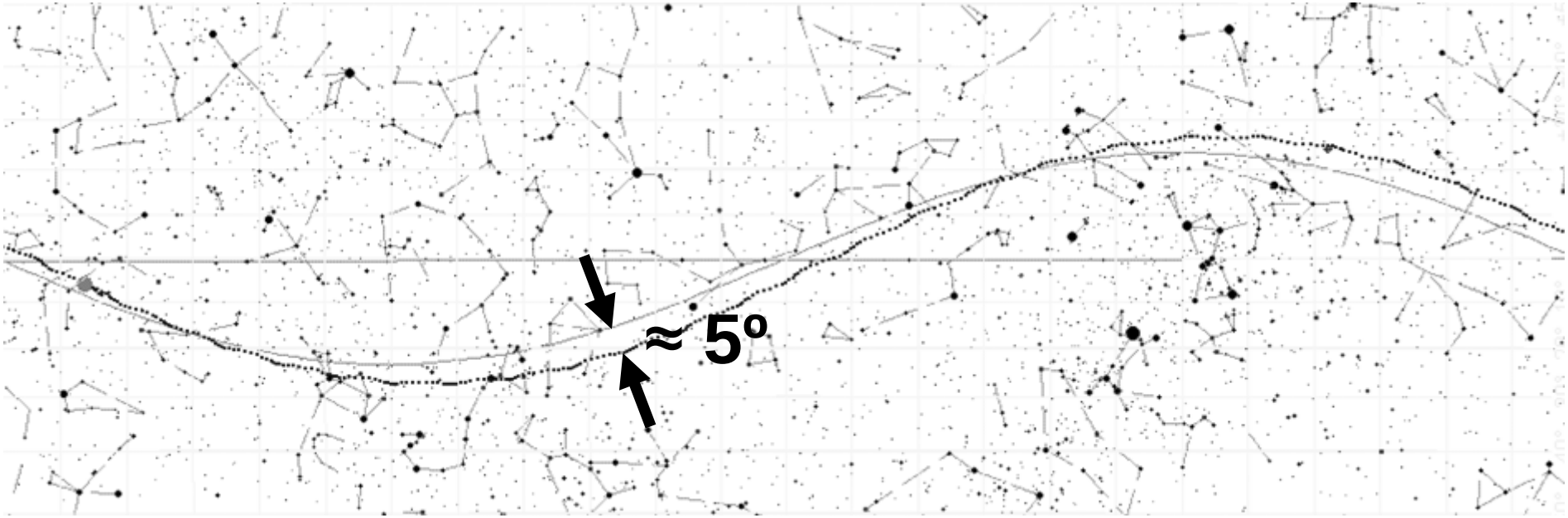


Libration is due to variation in the speed of the Moon in its elliptical orbit combined with the fact that its rate of spinning does *not* vary. As it steadily rotates and its speed increases or decreases we get a view skewed to one side or the other.

Some features “around the edge” or “beyond the limb” are visible only at certain times, depending on which way the Moon librates.

Moon's Path Relative to Stars

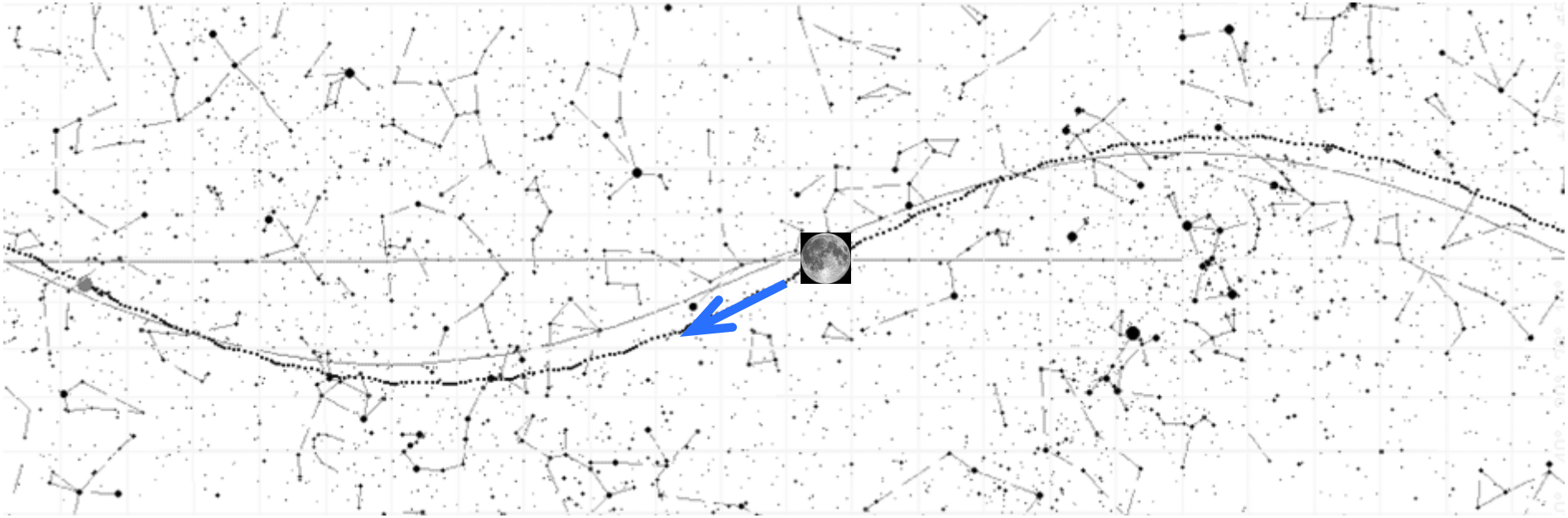
This path represents the orbit of the Moon. It never varies from the ecliptic by more than 5.3º.



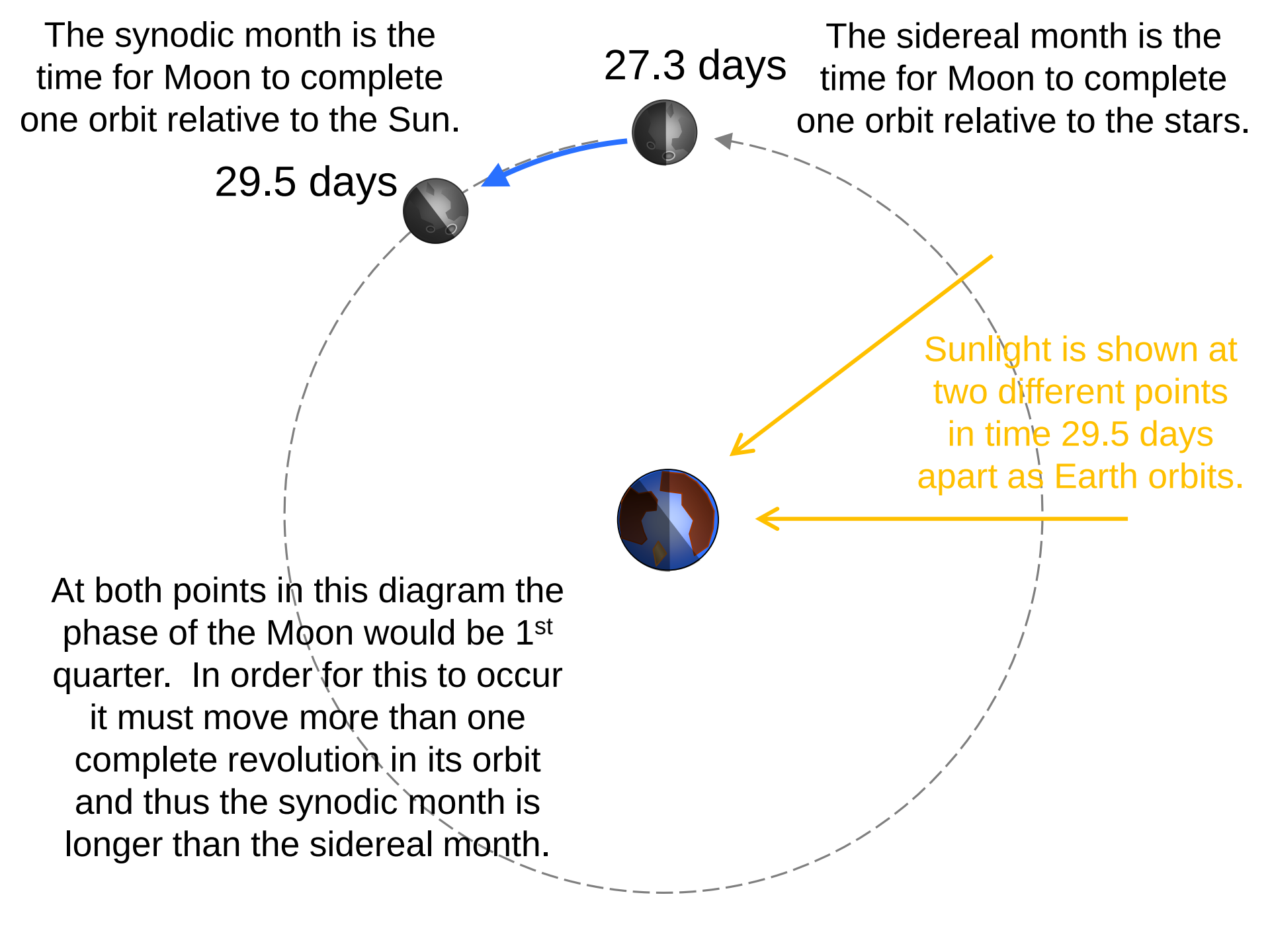
The plane of the Moon's orbit about Earth is tilted by about 5º relative to Earth's orbit about the Sun.

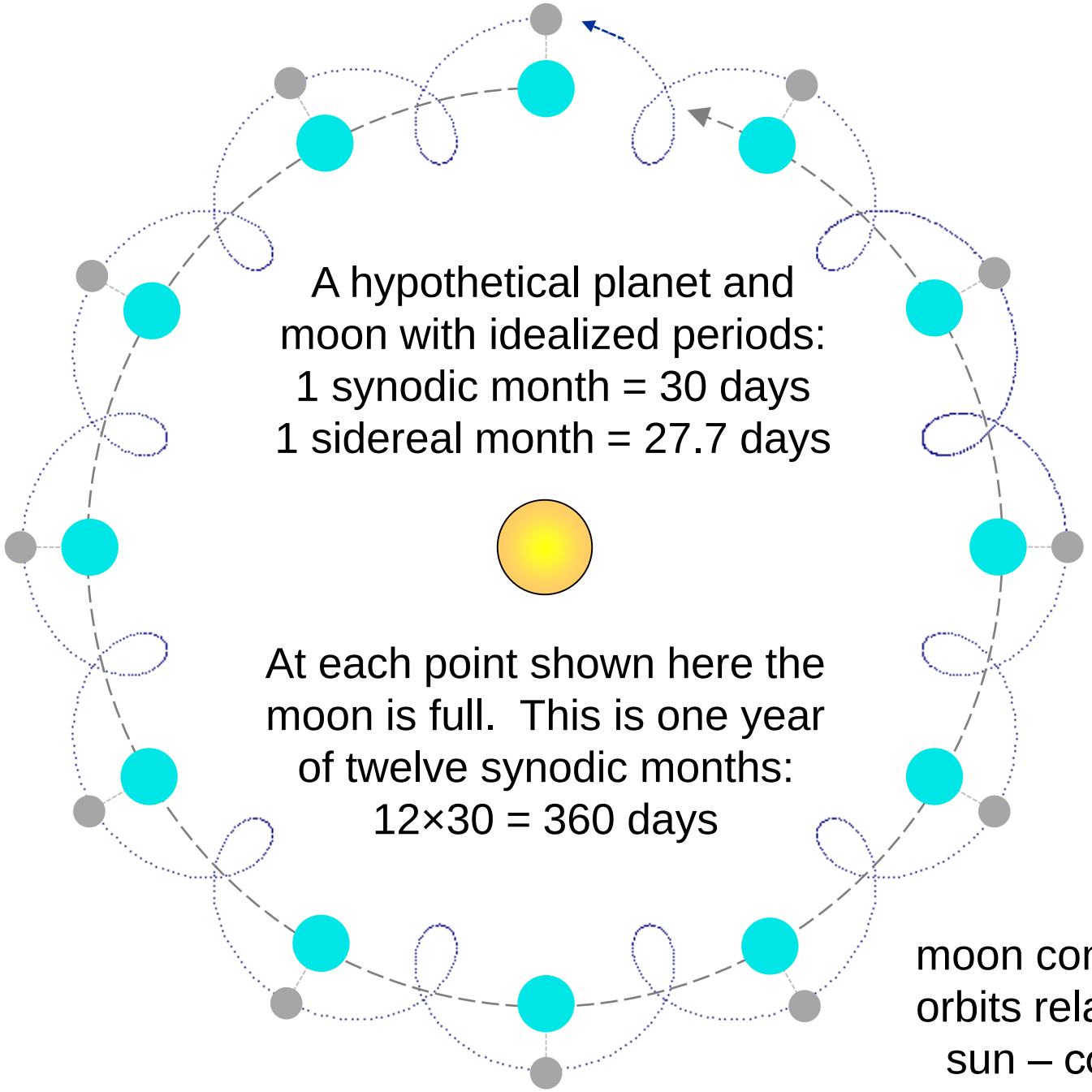
Moon's Path Relative to Stars

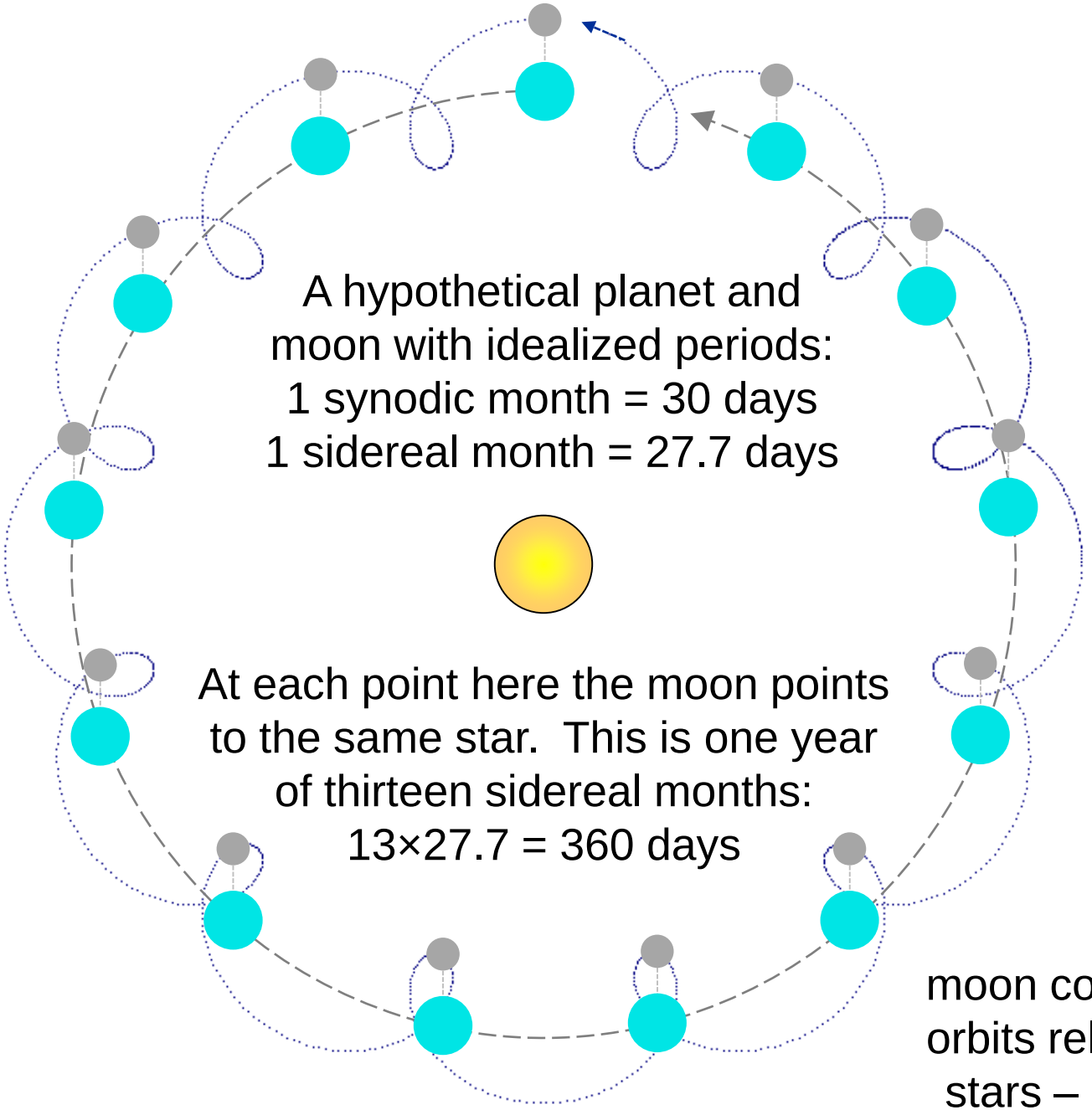
The time to complete one such path among the stars is called the **sidereal month**.



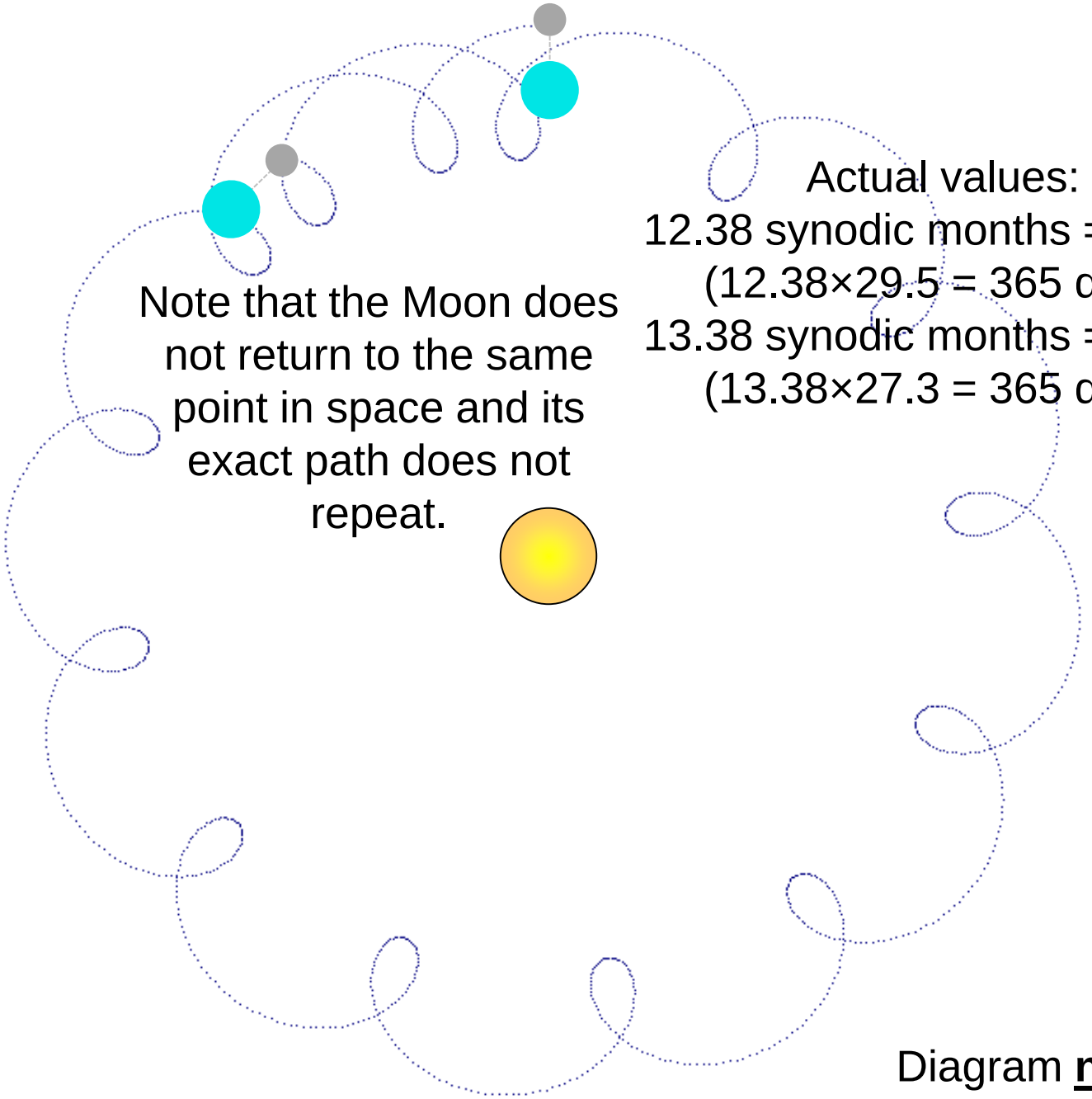
One sidereal month is about 27.3 days long.


The synodic month is the time for Moon to complete one orbit relative to the Sun.
27.3 days
The sidereal month is the time for Moon to complete one orbit relative to the stars.
29.5 days
Sunlight is shown at two different points in time 29.5 days apart as Earth orbits.
At both points in this diagram the phase of the Moon would be 1st quarter. In order for this to occur it must move more than one complete revolution in its orbit and thus the synodic month is longer than the sidereal month.


A hypothetical planet and
moon with idealized periods:
1 synodic month = 30 days
1 sidereal month = 27.7 days
At each point shown here the
moon is full. This is one year
of twelve synodic months:
12×30 = 360 days
moon completes 12
orbits relative to the
sun – count ‘em!



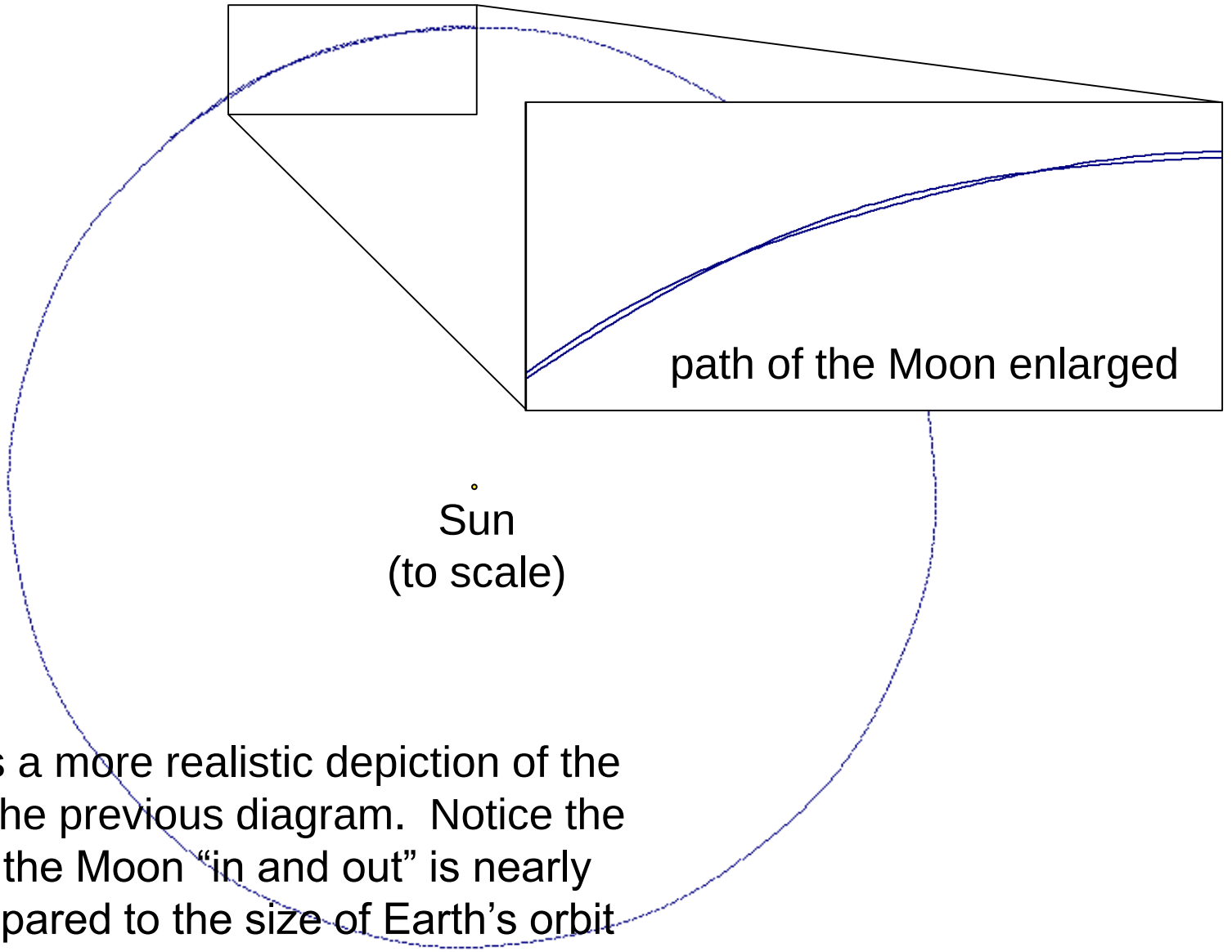
moon completes 13 orbits relative to the stars – count ‘em!



Note that the Moon does not return to the same point in space and its exact path does not repeat.

Actual values:
12.38 synodic months = 1 year
(12.38×29.5 = 365 days)
13.38 synodic months = 1 year
(13.38×27.3 = 365 days)

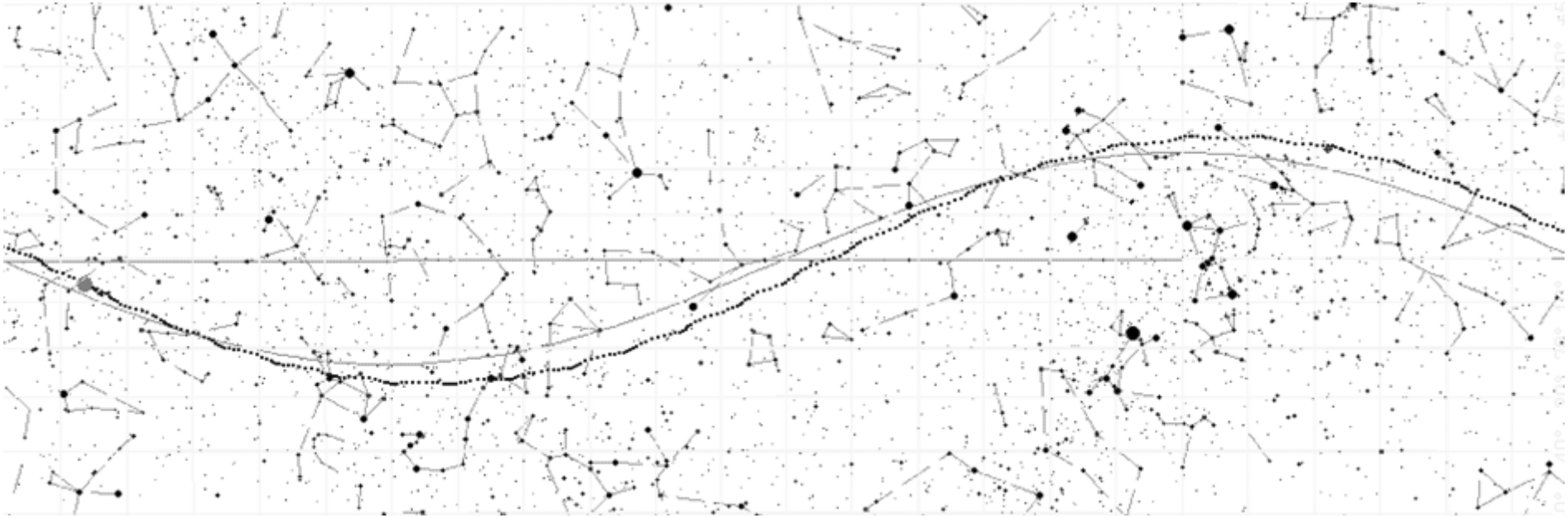
Diagram **not** to scale!



This diagram is a more realistic depiction of the path shown in the previous diagram. Notice the "wavering" of the Moon "in and out" is nearly invisible! Compared to the size of Earth's orbit the Sun is about 220 times smaller and the Moon's orbit about 400 times smaller.

Diagram **is** to scale!

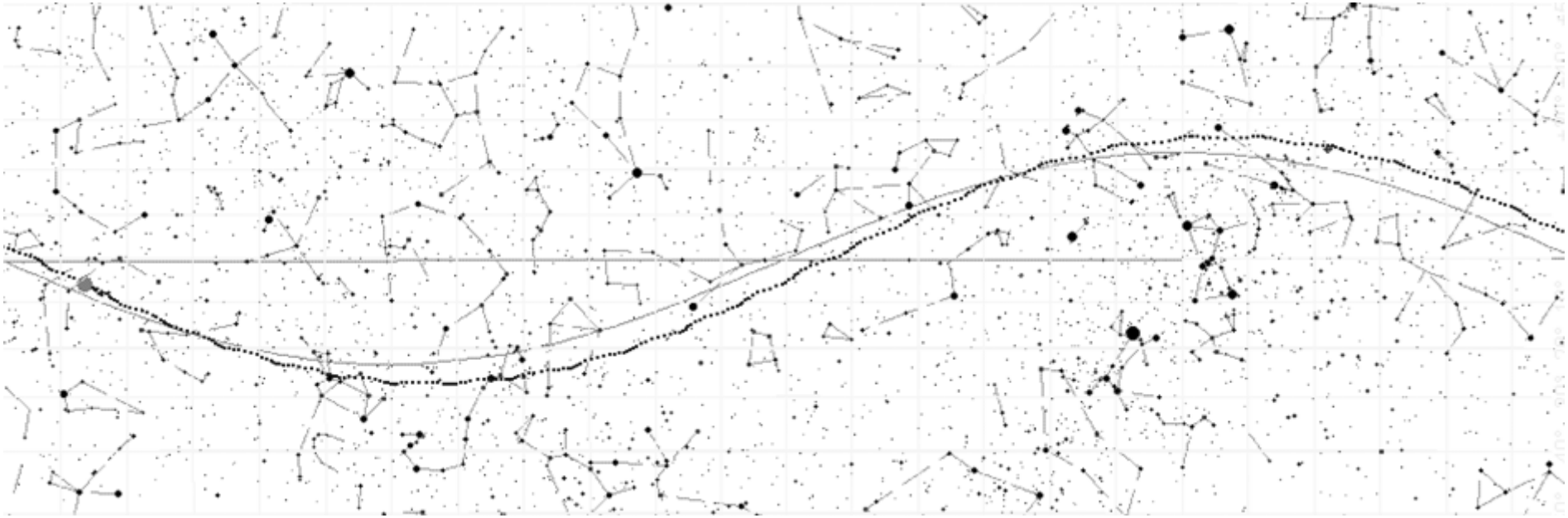
Moon's Path Relative to Stars



Is the path of the Moon shown on a star chart?

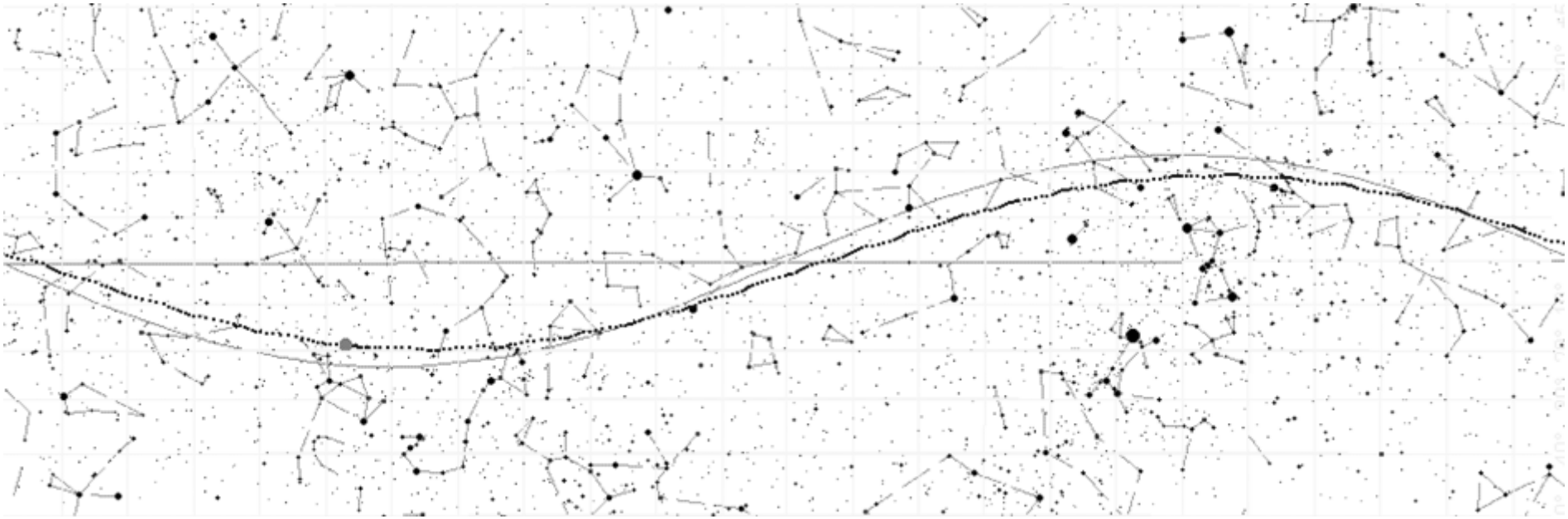
Why not?

Moon's Path Relative to Stars



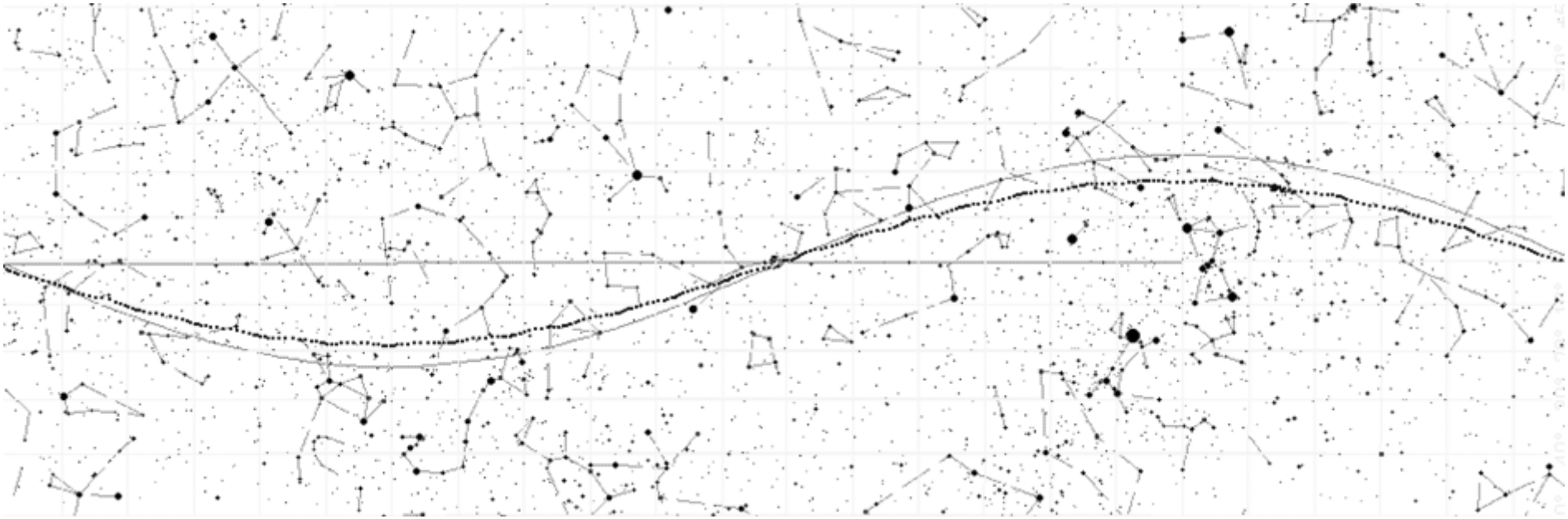
January, 2009

Moon’s Path Relative to Stars



January, 2014

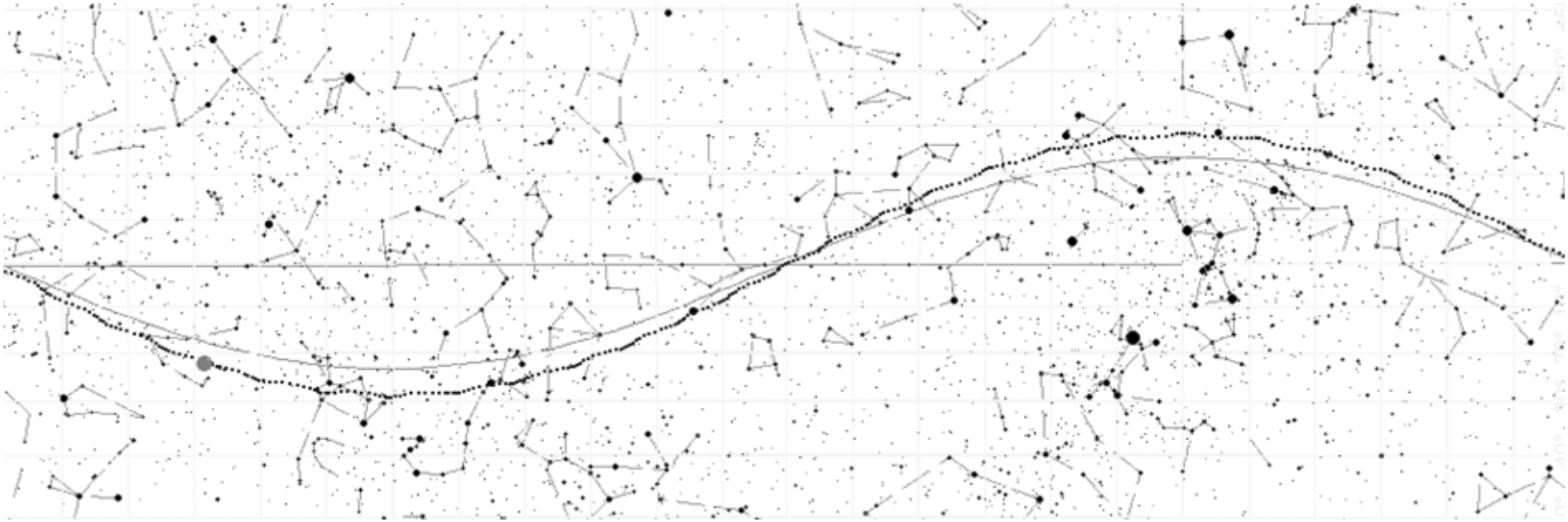
Moon’s Path Relative to Stars



January, 2016

Moon’s Path Relative to Stars

This cycle is *precession* of the Moon’s orbit.



January, 2025

This precession has a period of 18.61 years.

Practice with the Moon

On April 13, 2016 the Moon crossed the meridian at the same time the Sun was setting. Use planisphere, star charts, phase diagram, phase calendar, notes, etc.

1. What was the phase and approximate age?
2. It was located near or in what constellation(s)?
3. On what date(s) following this was the Moon next visible as a crescent above the east horizon?
4. On what date(s) following this was the Moon next located near or in the same constellation(s)? What was its phase then?

1. first quarter, approximately 7 days old 2. gemini and cancer 3. April 29 through May 3 (waning crescent) 4. May 10, which is 27 days later, it is waxing crescent